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Aerothermodynamics and Ground Test Facilities Simulation of Planetary Entry Flows: Application to Earth, Mars and Titan Atmospheric Entries

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The knowledge of the aerothermodynamic environment of space vehicles crossing the upper layers of planetary atmospheres at hypersonic velocities represents a critical issue for dimensioning purposes.

Such high-enthalpy flows present several additional challenges compared to more classical low-enthalpy flows. Dissociation and ionization effects take place which imply considering chemical reactions as well as radiation from the excited species present in the flow. Moreover strong departures from chemical and thermodynamic equilibrium are usually observed. In these particular case a set of three temperatures (translational-rotational temperature T_{tr}, vibrational temperature T_v and electron temperature T_e) is needed for a complete definition of the flow properties.

Different complementary ground test facilities allow the simulation of such entry condi- tions. Shock tubes such as the TCM2 facility in Marseilles, France, are representative of the compression flow in front of the vehicle. Plasma wind-tunnels, such as the SR5 arc-jet in Orléans, France, are representative of the high enthalpy ionized expansion flow in the back of the vehicle.

At the Laboratoire d'Aérothermique, investigations on Earth (Air), Mars (97% CO_2 - 3% N_2) and Titan (95% CH_4 - 5% N_2) like plasmas have been conducted over the last years [1][2]. Numerical investigations include the development and validation of the spectroscopic ra- diative code SESAM as well as the modelling of the SR5 plasma flow in a fluid mechanics approach using the ARES code and several other internal codes.

Experimental investigations include optical emission spectroscopy (OES) for the deter- mination of emitted radiation spectra as well as rotational and vibrational temperatures, laser induced fluorescence (LIF) for the determination of the flow velocity and translational temperature as well as species concentrations, and electrostatic probes measurements for the determination of the flow velocity as well as the electrons temperature and concentrations. Such measurements allow the validation of the numerical calculations mentioned before.

The complementary numerical and experimental investigations conducted at the Laboratoire d'Aérothermique allow an improved qualitative and quantitative knowledge on planetary entry flows which will lead to improved design properties and performance of future space ve- hicles.

References:

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